Experiences with a Prototype Implementation of DICOM Structured Reporting
Motivation

DICOM SR is fascinating from a scientific point of view:
- Structured information with well-defined semantics
- Enables automatic evaluation schemes (via codes)
- Large variety of applications in medicine
- Interoperability through use of "DICOM infrastructure"

Initial practical experiments with SR started in 1997 (frozen draft)

RFC from DICOM WG 14 and the Advancement Committee on a prototype implementation:
- SR together with the DICOM security extensions (TLS/signatures)
- Demonstration at RSNA 2000 and ECR 2001
DICOMscope and the OFFIS DICOM Toolkit (DCMTK)

DCMTK
- DICOM C/C++ class library
- Continuous development since 1993 (European CTN)
- Platform independent: Windows, Linux, Solaris, BSD, ...
- Open source freeware (BSD-like license)

DICOMscope
- Experimental Java based DICOM viewer
- Supports DICOM display consistency services
- Supports Print SCU and SCP including Presentation LUT
- Uses DCMTK (through Java JNI) for DICOM functionality
Module Structure of the DICOMscope Software

**DICOMscope / DCMTK**
- Java GUI
- JNI
- DCMPSTAT
- DCMSR
- DCMIMGLE
- IMAGE DB
- DCM NET
- DCM SIGN
- DCMDATA / OFSTD

**External Processes**
- Application
- DCMPSTAT
- DCMTLS
- DCMNET
- DCMDATA
- OFSTD

simplified presentation
New Components for Structured Reporting

- DCMTK Module "DCMSR"
  - Class library and command line tools
  - Reads, writes, creates, manipulates SR objects of all SR classes
  - Converts SR to XML, displays SR as text or HTML

- SR Viewer in DICOMscope
  - Renders complete SR documents in HTML
  - Displays referenced images / p-states as hyperlinks

- SR Editor in DICOMscope
  - Visualizes the tree-like content structure of SR
  - Allows to edit header fields and content items
  - Allows to insert and delete content items

- Creates and verifies Digital Signatures in SR documents
Class Hierarchy of DCMSR

DSRTypes

DSRTreeNode

DSRTreeNodeCursor

DSRDocument

DSRContentItem

DSRTree

DSRDocumentTree

OFList

DSRListOfItems

DSRCompositeReferenceValue

DSRWaveformReferenceValue

DSRDateTimeTreeNode

DSRCompositeTreeNode

DSRByReferenceTreeNode

DSRContainerTreeNode

DSRCodeTreeNode

DSRNumTreeNode

DSRSCodeTreeNode

DSRSRCoordTreeNode

DSRTCoordTreeNode

DSRDDateTimeNode

DSRTimeTreeNode

DSRUIDRefTreeNode

DSRTextTreeNode

DSRGraphicTreeNode

DSRGraphicDataItem

DSRImageTreeNode

DSRReferencedSamplePositionList

DSRWaveformChannelList

DSRWaveformChannelItem

DSRGraphicDataList

DSRImageFrameList

DSRReferencedDatetimeList

DSRReferencedSamplePositionList

DSRReferencedTimeOffsetList

DSRReferencedDateTimeList

DSRNumericMeasurementValue

DSRSpatialCoordinatesValue

DSRTemporalCoordinatesValue

DSRStringValue

DSRStringTreeNode

DSRGraphicTreeNode

DSRGraphicDataItem
Design Decisions

- SR SOP Class is determined at object instantiation.
- During manipulation of the content tree, the integrity conditions of the SR class are enforced by the library.
- Generation of new SOP Instance UID only on explicit request.
- Read routine validates the integrity of the SR document and reports violations of the standard (IOD structure).
- Document management: semantics of complete/verify/revise.
Not all state transitions shown in figure.
Textual Dump of a Comprehensive SR Document

Patient: Homer^Jane^^ (F, 19991109, #234567)
Referring Physician: Luke^Will^^Dr.^M.D.
Manufacturer: WG6
Completion Flag: COMPLETE
Verification Flag: VERIFIED

Content Date/Time: 19991029, 154510
1 <CONTAINER (,,"Chest X-Ray")=SEPARATE>
  1.1 <has obs context PNAME (,,"Recording Observer")="Smith^John^^Dr^">  
  1.2 <has obs context UIDREF (,,"Study Instance UID...")="1.2.3.4.5.6.7.100">  
  1.3 <has obs context PNAME (,,"Patient-Data-Acquisition Subject")="Homer^Jane^^">  
  1.4 <contains CODE (,,"Finding")=(000333,99STElsewhere,"Mass")>
  1.4.1 <has properties NUM (,,"Diameter")="1.3" (000111,SNMdemo,"cm")>
  1.4.2 <has properties CODE (,,"Margination")=(222000,SNMdemo,"Infiltrative")>
  1.5 <contains IMAGE (,,"Baseline")="1.2.3.4";>
  1.6 <contains CONTAINER (,,"Conclusions")=SEPARATE>
    1.6.1 <contains CODE (,,"Conclusion")=(888000,99STElsewhere,"Probable malignancy")>
    1.6.1.1 <inferred from 1.4.2>
    1.6.1.2 <inferred from 1.7.1>
  1.7 <contains CONTAINER (999000,LNdemo,"Specific Image Findings")=SEPARATE>
    1.7.1 <contains SCOORD (833000,SNMdemo,"Best illustration of findings")
      =(POLYLINE,0/0,0/0,0/0,0/0,0/0)>
    1.7.1.1 <selected from IMAGE =("1.2.3.4";)
  1.8 <has concept mod CODE (123456,LNdemo,"Views")=(123457,LNdemo,"PA and Lateral")>

Format similar to proposal from D. Clunie's SR book

Node position for by-reference relationships

Concept name
Creation of HTML from SR

- Output format: HTML 3.2/4.0, CSS, DTD
- Maps DICOM character sets to HTML 3.2/4.0 as far as possible
- References in the SR document are mapped to pseudo-hyperlinks
- Degree of detail is configurable:
  - Under which circumstances is a code displayed
  - Which components of a code are shown
  - In which cases are content items moved into separate sections of the HTML document and linked with hyperlinks
This 78-year-old gentleman referred by Dr. Fukuda was also seen by Dr. Mason at the Redlands Clinic. He has been seen in the past by Dr. Klugman.

The patient developed a lesion in the concha of the left external ear. Recent biopsy confirmed this as being a squamous cell carcinoma. The patient has had a few other skin cancers. Of most significant past history is the fact that this patient has a leukemia that has been treated in standard fashion by Dr. Klugman.

The patient was then transferred to the Redlands Clinic and by some experimental protocol which, I guess, includes some sort of lymphocyte electrophoresis, has been placed into remission. He is not currently on any antileukemia drugs and has responded extremely well to his medical management.

On examination, the patient is healthy in general appearance. There is a 1.5 cm lesion on the concha of the ear, which is seen well on photograph of the left external ear. There are numerous soft lymph nodes in both sides of the neck, which I presume are related to his leukemia.

**Diagnosis:**
Squamous cell carcinoma, relatively superficial, involving the skin of the left external ear, which is seen well on photograph of the left external ear.

**Treatment:**
The plan of treatment is as follows: 4500 rad, 15 treatment sessions, using 100 kV radiation.
The reason for treatment, expected acute reaction, and remote possibility of complication was discussed with this patient at some length, and he accepted therapy as outlined.
Creation of XML from SR

- So far no standardized transformation SR ➔ XML exists

- Required design decisions:
  - Transformation lossy or lossless?
  - How close should the XML document be to the SR model?
  - What is mapped to an XML tag, attribute or element?
  - How are "by reference" relationships handled?

- Problems
  - Validation of document correctness: different expression power of DICOM SR-IOD / XML DTD / XML Schema
  - Mapping of DICOM character sets to Unicode?

- "On the horizon": HL7 Clinical Document Architecture Level 1-3
<item valType="PNAME" relType="HAS OBS CONTEXT">
  <concept>
    <value>000555</value>
    <scheme>
      <designator>LNdemo</designator>
    </scheme>
    <meaning>Recording Observer</meaning>
  </concept>
  <value>
    <prefix>Dr</prefix>
    <first>John</first>
    <last>Smith</last>
  </value>
</item>
SR Editor in DICOMscope

- Supports editing of arbitrary SR documents of all SR classes

- "Technical" approach: completeness instead of medical usability is to the fore

- Editor GUI is divided into
  - "Tree view" for the hierarchical SR structure
  - Dialog for the currently selected entry in the SR tree, depending on content item value type

- Context menus allow to manipulate tree structure

- Visualization of "by reference" relationships problematic
Codes and Controlled Terminology

- Consist (at least) of: coding scheme designator, code value, code meaning

- Describe concepts, units, persons, diagnoses, anatomical structures, ...

- Enable automatic evaluation of SR documents

- Current implementation in our software:
  - Loadable "dictionary", not hard-coded
  - Sorted by context groups (GUI dialogs are based on context groups)
  - Code semantics not used, just "code meaning" for display
Problems and Challenges

- Very general structure (framework), becomes useable only through application specific templates

- Appropriate rendering requires sector knowledge about the used coding schemes and code semantics

- Visualization of third party reports of unknown structure difficult

- Intuitive GUI for medical user with application intelligence (coding etc.) in the background?

- Semantics of SR document management flags undefined

- Cyclic structures in comprehensive SR possible!
SR and Digital Signatures

Digital Signatures in DICOM: Supplement 41 (Draft)

Use of digital signatures in SR makes sense:
- Digital archival in accordance with the EU directive
- Assignment of roles and rights based on certificates
- Possibility to use "health professional cards"

Problems
- No clear rules about what/when/how to sign are defined
- Relationship between SR document management and digital signatures not defined
- Multiple verifying observers creating digital signatures (signatures can become invalid)
Conclusion

❌ SR: great potential but many open questions
   ✦ Intelligent GUI for interactive creation of SRs
   ✦ Templates for many fields of application not yet defined
     (on which level: international, national, local?)

❌ Prototype Software: freely available from
   http://www.microtherapy.de/go/dicomscope/
   http://www.offis.de/projekte/dicom/
   ftp://dicom.offis.uni-oldenburg.de/pub/dicom/offis/software/

⏩ And now for the demo...